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Nonconformity of policy ambitions with biomass potentials in regional bioenergy transition: A Dutch example

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HIGHLIGHTS

- Biomass resource potential assessment performed with Dutch province as case study.
- Methodology presented to translate technical biomass potential into policy domain.
- Nonconformity found between the province's policy ambition and biomass potential.
- Five policy measures identified to cope with this nonconformity.

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ABSTRACT

Numerous regional authorities within the European Union are committed to meet renewable energy targets in line with the EU-20-20-20 strategy. Energy from biomass occupies a pivotal position in the renewable energy strategy of many regions. Effective bioenergy policy often depends on an assessment of the regional resource potential for energy from biomass. Using the Dutch province of Overijssel as a case study, this study presents a biomass resource potential assessment, based on existing statistics and a resource-focused methodology, to determine the region's theoretical and technical potential. Additionally, a methodological framework is provided to translate the outcome of this biomass resource potential assessment into the policy domain, to allow the region's bioenergy policy ambition to be evaluated. The results indicate that Overijssel's potential bioenergy target is a share of 8.3%, which does not match with the desired policy target of 14%. It is therefore clear that it is unlikely that the province's bioenergy ambition will be met with the current supply of biomass, in the absence of additional policy measures. The outcome of the biomass resource potential assessment has therefore been used to deduce and recommend multiple policy measures.

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1. Introduction

The increasing concern for security of supply and climate change has redefined the priorities of energy policy across Europe (Helm, 2007). The European Union has recognized these challenges and approached them with new élan and considerable momentum, to shape a common energy policy based on security of supply, competitiveness and sustainability (European Commission, 2007). Significant legislative progress has been demonstrated with the adoption of the EU Climate and Energy Package, which incorporates the EU 20-20-20 targets for climate change and energy. As part of this package, RES Directive 2009/28/EC sets binding national targets for the share of renewable energy sources in the total energy consumption such that an EU-average share of 20% will be reached by 2020. The binding national target for the Netherlands has been set at 14%. Moreover, each Member State is committed to a mandatory share of 10% renewable energy in transportation.

The diversification of the energy mix with renewable energy sources is thus a key objective of the EU's common energy strategy. Currently, energy from biomass – including waste – is the largest source of renewable energy consumed in the EU-27, representing a 69% share of the total renewable energy consumption in 2010, which is almost 9% of the EU's total energy consumption (European Commission, 2012). Similar figures are found for the Netherlands, where energy from biomass takes a 74% share in the total renewable energy consumption (Statistics Netherlands, 2012). As a consequence, biomass is a dominant renewable energy source for heating, power generation and transportation fuels. It thus occupies a pivotal position in current strategies to meet the EU 20-20-20 targets.

These strategies are not only addressed at supranational and national level; a great deal of momentum is also transferred to

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regional and local levels. An example of regional and local engagement is the Covenant of Mayors, which commits local authorities to meet self-imposed climate and energy targets.

The physical characteristics of biomass also encourage regional or local bioenergy solutions. Due to the low energy density and low mass density of unprocessed biomass, for example, it is more favorable to limit the distance over which biomass is transported by keeping the harvest and the initial processing steps close together. Moreover, effectively closing the mineral balance of biomass demands local biomass utilization and processing. Furthermore, since the availability of biomass resources is determined geographically, regions with high biomass availability have an additional incentive to opt for bioenergy development.

Although bioenergy complies with the climate change and renewable energy ambitions of many regions, there is still a need for a quantitative assessment of the biomass resource potential to analyze the regional potential for energy from biomass. This analysis can subsequently be used to support bioenergy policy making. For that reason, the biomass resource potential of numerous cases is broadly assessed for different types of potentials, with multiple approaches and various methodologies (Batidzirai et al., 2012). As an addition to the common literature, this paper presents a resource-focused methodology, based on existing statistical data, to assess the technical biomass potential of the Dutch province of Overijssel. This technical biomass potential is introduced in dimensionless form by evaluating it in the context of regional energy consumption. The dimensionless technical biomass potential is then used as a basis for further policy analysis.

The objective of this study is not only to identify the biomass resource potential of the Dutch province of Overijssel, but also to provide a methodological framework to translate the outcome of a biomass resource potential assessment into the policy domain, thus allowing the bioenergy policy ambition of the province of Overijssel to be evaluated.

2. Province of Overijssel

The province of Overijssel is chosen as the case study region for the biomass resource potential assessment. This province is located in the eastern part of the Netherlands and houses 1.3 million inhabitants in 25 municipalities, with a total surface area of 3421 km^2 (Fig. 1). Nearly half of the population (47%) lives in five urban municipalities, while the remainder is scattered among eighteen rural municipalities and two small-urban municipalities; the last two have a marginal population count but a high population density. As a result, the province can be characterized as multiple urban agglomerations compactly situated within a highly rural landscape.

The land use in the province is mainly agriculture (70%), followed by nature reserves (14%) and built-up area (13%). The cultivated land is primarily used as pasture land (71%) and to grow fodder (21%), with other arable farming activities (7%) and horticulture (1%) taking a minor share (Statistics Netherlands, 2013). As these statistics indicate, agricultural activity in Overijssel is predominantly cattle farming. As a consequence of the large livestock herd and regulatory restrictions on fertilizer use, Overijssel has a surplus of manure available.

The province is furthermore committed to the EU target of 20% renewable energy consumption in 2020 (Province of Overijssel, 2011). A special policy program – *Programma Nieuwe Energie* – has been adopted and implemented to achieve this ambition. This program places a great emphasis on reducing energy consumption in the built environment, and renewable energy production from biomass. Considerable financial resources are also reserved to achieve this renewable energy ambition, with the establishment of a 250M€ fund for soft loans.

Currently, almost 6% of the energy consumption in the province is met from renewable energy sources. Biomass is the main renewable energy source, taking a 90% share in the province's renewable energy portfolio. This share is composed mainly of waste incineration, woody biomass combustion and first generation biofuel production. The province's objective is to maintain bioenergy as the primary source for renewable energy: a minimum share of 70% within the renewable energy portfolio is envisioned. It is therefore clear that an expansion of the provincial renewable energy capacity is required to meet the adopted 20% renewable energy target and the underlying 14% bioenergy target by 2020. However, since no comprehensive potential study has ever been published, to the authors' knowledge, the real potential for bioenergy development in the province of Overijssel is unknown. For that reason, it is useful to conduct an assessment of the province's biomass resource potential.

3. Methodology

Different methodological frameworks have been used previously to conduct biomass resource potential assessments. Batidzirai et al. (2012) reviewed the current methodological heterogeneity by categorizing studies according to the type of potential, approach and methodology used. Following the categorization and terminology of Batidzirai et al. (2012), this paper presents a resource-focused statistical analysis as the overarching methodological framework to determine the technical biomass potential. This methodological framework is depicted in Fig. 2. As this framework only applies to a single case study region and only accounts for local biomass resources, biomass trade is excluded from the calculations of the biomass resource potential.

In this study the technical biomass potential is defined as the amount of bioenergy that can be produced on the basis of the theoretically available amount of biomass resources, constrained by the technical options available in the region under study. It is thus necessary first of all to determine the theoretical biomass potential. As specified by Chum et al. (2011), the theoretical potential describes the biomass supply that is theoretically available within biophysical limits. It is therefore found by collecting data on the available biomass resources.

The theoretical potential can subsequently be cascaded into the technical potential by taking technical limitations and competing biomass allocations into account. The technical limitations here are imposed on the basis of two bounding scenarios, so that the technical potential is presented within an upper and a lower technological bound. The resulting technical potential is then evaluated within the context of energy consumption in the case study region. A dimensionless technical potential is therefore introduced by dividing the technical potential by the corresponding energy consumption. This dimensionless technical potential hence describes the potential share of bioenergy in the current energy consumption. The result of the biomass resource potential assessment can then be translated into the definition of the regional policy ambitions.

3.1. Classification of biomass

A classification of biomass resources is needed to organize the acquired data. Six main categories of biomass resources are therefore identified: woody biomass, agricultural residues, grasses, manure, municipal solid waste, and other biomass. The various types of biomass are subsequently grouped within these main categories. Twenty relevant types of biomass have been distinguished in the case

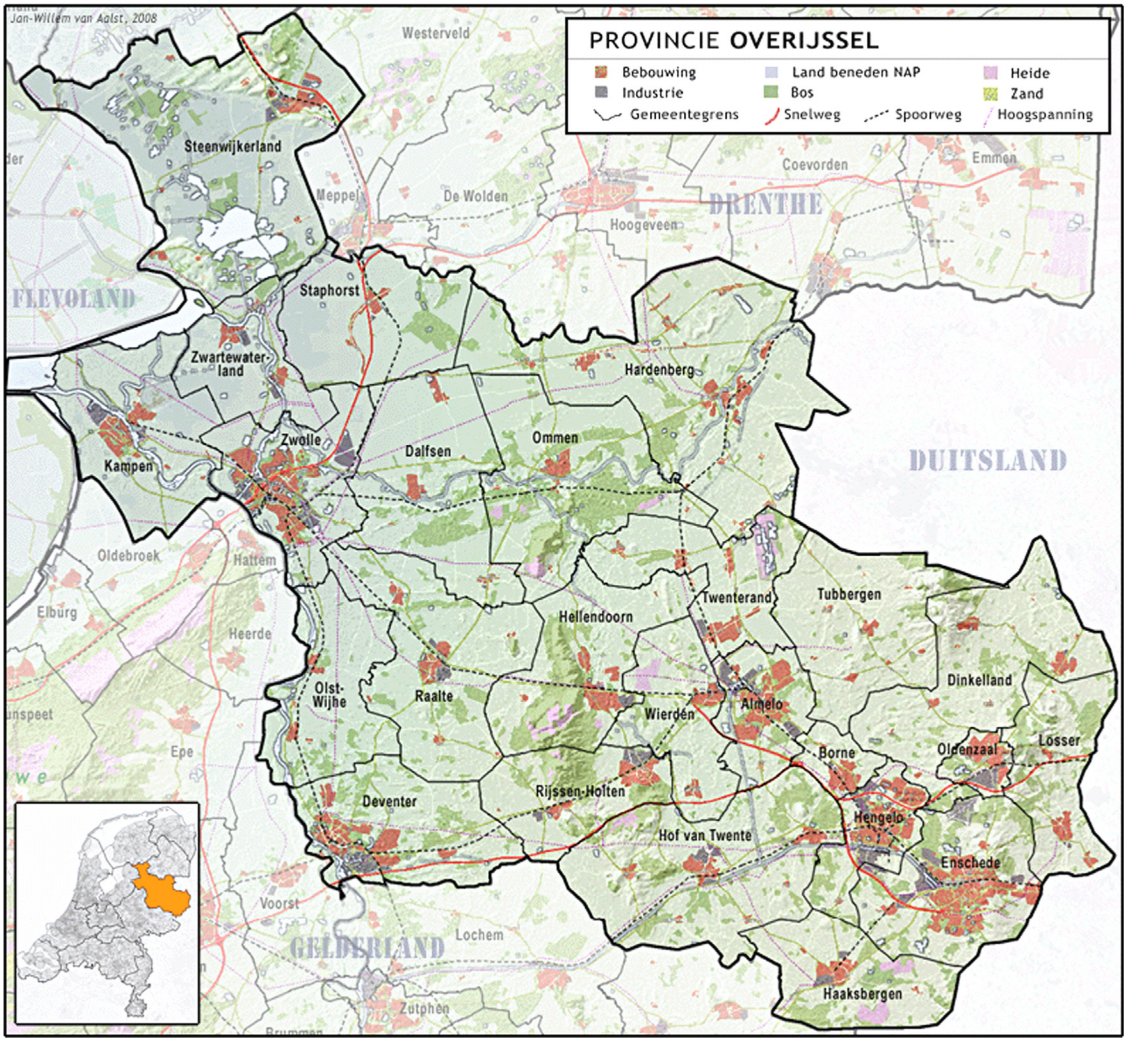


Fig. 1. Map of the Dutch province of Overijssel.

study region: see Table 1 for the resource classification. It should be noted further that the main category of *other biomass* – containing the biomass types algae, sludge and food processing waste – is not considered in this study due to the absence of data on the municipality level. This omission is acceptable because these biomass streams are either marginal in amount or already fully allocated to non-energy markets in the province of Overijssel.

3.2. *Theoretical biomass resource potential*

The theoretical biomass resource potential is found by collecting and processing data for each of the classified types of biomass. The initial data on biomass resources have in nearly all cases been obtained from (Statistics Netherlands, 2013). Only two types of biomass – reed and natural grasses – are derived from an alternative source (Arcadis, 2012). All data are here aggregated at municipality level to afford a spatial dimension to this study.

Complementary data from existing literature and other databases is then used to process the initial data on biomass resources into the theoretical potential. The types of biomass that are initially expressed in terms of surface area – such as grassland for hay, forest area for landscape wood, and cultivated area for agricultural residues – are converted to units of mass using a harvest factor. The harvest factor for hay is found by multiplying the annually mown surface area of grassland by a grass yield of 2.09 t/ha (Statistics Netherlands, 2013); in case of fresh wood from forestry a harvest factor of 3.2 t/ha is derived from Probos (2012); the harvest factor for all agricultural residues is found by weight averaging crop yield data for the corresponding year (Statistics Netherlands, 2013). This factor includes a product-to-residue ratio, taken from Unal and Alibas (2007) for the various crops, and an estimated residue removal rate of 50% from the land. The conversion factors used are given in Table 2.

After these initial data processing steps, all types of biomass can be expressed in terms of mass. This amount of biomass is given as wet weight, however. For that reason the Phyllis database is used to estimate the moisture content for each type of biomass (ECN, 2013). This value is then used to compute the amount of dry mass for each type of biomass. The conversion step from dry mass to energy is subsequently taken by multiplying the resulting amount of biomass for each type by the corresponding energy content. The energy content is here represented by the higher heating value (HHV), which is also derived for each type of biomass from the Phyllis database (ECN, 2013). As a result of the energy conversion step, the theoretical resource biomass potential is now described in the desired units of energy. The theoretical biomass potential is hence found.

3.3. *Technical biomass resource potential*

The theoretical biomass potential merely gives a description of the amount of energy from biomass resources that are theoretically available in the case study region. A more representative biomass is potential is found after cascading the theoretical potential into the technical biomass potential. The availability of the theoretical potential for bioenergy is assessed first. This is done by considering two conditions: the evaluated biomass resource is either not available due to an alternative allocation to a non-energy market, or the biomass resource is not available because it is already being utilized for energy.

Applying these conditions significantly reduces the theoretical potential of some biomass categories. It is found that the main category of municipal solid waste and biomass of the type waste wood are completely unavailable in the case study region, because these waste streams are already successfully being used for energy production, recycling or composting. Agricultural residues are also largely unavailable for bioenergy due to competing demands – i.e. straw and crop residues have an existing destination as fodder and farm material. Although the market for agricultural residues is competitive and price-driven, it is estimated that only 10% of the agricultural residues will be available for bioenergy. Similar conditions apply to hay from grassland, since hay is mainly allocated as animal feed or stable cover. Statistics show that only 3% is allocated differently (Statistics Netherlands, 2013). An availability of 3% is hence taken for this type of biomass. The remaining types of biomass are, on the other hand, fully available for bioenergy. It is estimated that all landscape wood can be utilized for energy because no existing or alternative use has been found. Reed and natural grasses are also available, because their availability for bioenergy had already been taken into account by the source of the data (Arcadis, 2012). The theoretical potential of manure is also entirely available for bioenergy, since the initial data describe the surplus of manure in the case study region.

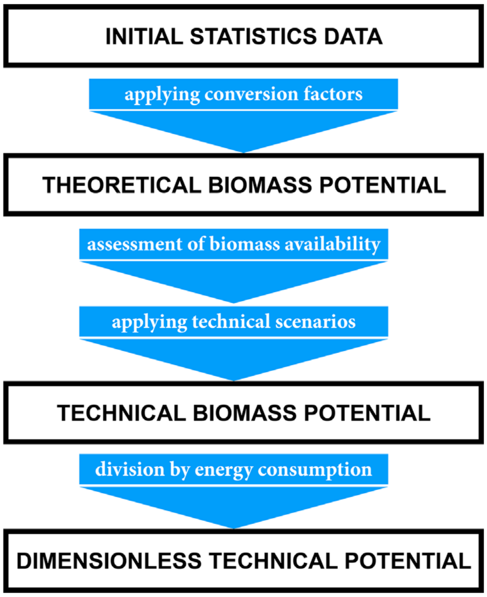

INITIAL STATISTICS DATA
applying conversion factors
THEORETICAL BIOMASS POTENTIAL
assessment of biomass availability
applying technical scenarios
TECHNICAL BIOMASS POTENTIAL
division by energy consumption
DIMENSIONLESS TECHNICAL POTENTIAL

Fig. 2. Methodology of the biomass resource potential assessment.

After the evaluation of the availability of the theoretical biomass potential, an assessment is made of the current technological possibilities to convert these biomass resources into bioenergy. Technical constraints are thus considered to find the technical biomass potential. These constraints are imposed upon the available theoretical potential by assigning appropriate bioenergy technologies to each type of biomass. Since many routes are offered to convert various types of biomass into three different energy products – viz., heat, power and fuel – a choice is made to compute a technical potential for each energy product by selecting matching technologies. A second choice is made to represent these technical potentials within the interval of two bounding scenarios. The lower technological bound is here defined by the *current case* scenario – in which proven and currently employed technological routes are selected to convert the biomass into energy. Conversely, the upper bound is defined by the *innovation* scenario – in which demonstrated technological routes are selected that are locally upcoming. As a result, the technical biomass potential is described by an area, spanned by six technical potential values. An average technical biomass potential is obtained by taking the mean of these six technical potential values.

Table 3 shows the selected technological route for each category of biomass. It also gives the used energy efficiencies, which are derived from International Energy Agency (2007), Agentschap NL (2011) and Bridgwater (2012). Several comments should be made on these

Table 1
Biomass classification.

Main category	Type of biomass	Additional description
Woody biomass	Landscape wood	Wood harvested from natural landscape
	Waste wood	Waste wood (classes A, B and C)
Agricultural residues	Grains	Residues from wheat, barley, rye, oat, triticale and maize
	Commercial crops	Residues from rapeseed, hemp and chicory
	Fodder crops	Residues from green maize (fodder)
	Sugar beet	Residues from sugar beet plant
Grasses	Hay from grasslands	Hay from agricultural pasture land
	Reed	Reed extracted from natural areas
	Natural grasses	Natural grasses (e.g. heath) extracted from natural areas
Manure	Cattle manure	Manure from dairy and beef production excluding veal
	Veal manure	Manure from young cattle for beef production
	Chicken manure	Solid manure from poultry
	Pig manure	Liquid manure from intensive pig farming
Municipal solid waste	Domestic waste	Non-organic fraction of collected household waste
	Coarse domestic waste	Domestic waste that is collected separately due to its large size for regular collection by the municipality.
	Organic waste	Includes domestic organic waste, coarse garden waste and green waste from municipal maintenance
	Paper waste	Collected paper and cardboard
Other biomass	Sludge	Sludge from domestic sewage and industry
	Industrial food processing waste	Residual streams from the food processing industry
	Algae	Biomass from algae farms (predominantly pilot plants)

Table 2
Conversion factors used in biomass resource potential assessment.

Main category	**Type of biomass**	**Harvest factor** (t/ha)	**Moisture content** (%)	**Higher heating value** (GJ/t)	**Availability** (%)
Woody biomass	Landscape wood	3.2	50	18.4	100
	Waste wood	–	15	20.1	0
Agricultural residues	Grains	5.1[a]	14	18.4	10
	Commercial crops	5.0[a]	14	18.4	10
	Fodder crops	32.0[a]	69	18.5	10
	Sugar beet	14.9[b]	87	17.7	10
Grasses	Hay from grasslands	5.9	60	18.5	3
	Reed	–	17	17.2	100
	Natural grasses	–	17	18.3	100
Manure	Cattle manure	–	78	14.6	100
	Veal manure	–	78	14.6	100
	Chicken manure	–	38	14.6	100
	Pig manure	–	69	13.8	100
Municipal solid waste	Domestic waste	–	22	14.7	0
	Coarse domestic waste	–	22	14.7	0
	Organic waste	–	39;15[c]	15.0	0
	Paper waste	–	8	17.1	0
Other biomass	Sludge	–	–	–	–
	Industrial food processing waste	–	–	–	–
	Algae	–	–	–	–

[a] Harvest factor is weight averaged of each crop for this type of biomass. It also includes an average residue-to-product ratio of 1.3 and an estimated residue removal rate of 50% from the land.

[b] Harvest factor includes a residue-to-product ratio of 0.4 and an estimated residue removal rate of 50% from the land.

[c] Since organic waste is composed of different sources of biomass, the moisture content is also different. Moisture content for organic waste streams is 39% while the moisture content for coarse garden waste is 15%.

Table 3
Conversion factors used in biomass resource potential assessment.

Scenario	Energy product	Biomass category			
		Woody biomass	Agricultural residues	Grasses	Manure
Current case	Heat	A	A	A	B
	Power	C	D	D	D
	Fuel	E	F	F	F
Innovation	Heat	A	A	A	B
	Power	C	G	G	D
	Fuel	E	E	E	F

Code	Description	Energy product	Overall energy efficiency
A	Direct combustion	Heat	0.8
B	Digestion + biogas combustion	Heat	0.04
C	Combined Heat and Power (CHP)	Power + heat	0.3 (power); 0.5 (heat)
D	Digestion + biogas engine for power	Power	0.02[a]; 0.06[b]
E	Pyrolysis oil production	Fuel	0.7
F	Digestion + biogas production	Fuel	0.05[a]; 0.20[b]
G	Pyrolysis + pyrolysis oil co-firing	Power	0.28

The upper table contains capital letters which refer to various technological conversion pathways. These conversion pathways are described in the lower table with corresponding energy product and conversion factor (overall energy efficiency).

[a] In case of manure.

[b] In case of agricultural residues or grasses.

selections. In the category of manure and woody biomass identical technologies are selected for both scenarios. It is assumed that the upcoming technological solutions for these types of biomass will remain unchanged in the case study region. Digestion is in fact the only proven technology for converting manure into energy products. Alternative conversion routes for manure – such as wet torrefaction – are considered promising, but are still too immature for application within the time period of the policy ambition. Pyrolysis, on the other hand, is selected in both scenarios to determine the fuel potential for woody biomass, since wood pyrolysis is experimentally proven within the case study region and the erection of a wood-based pyrolysis oil factory has recently been initiated in Overijssel. Pyrolysis is moreover selected as an innovative technology to produce power and fuel from agricultural residues and grasses. The co-firing of grass-based pyrolysis oil has been demonstrated in a regional coal fired power plant, but it remains an upcoming technology for these two biomass categories due to a lack of commercial applications (BTG-BTL, 2004). Furthermore, direct combustion has been selected in all cases as the dominant technology for determining the technical heat potential, since combustion is the most efficient way to produce heat. Finally, Combined Heat and Power (CHP) technology is selected to compute the power potential in both scenarios for the category of woody biomass. Although heat is physically not equal to power, the overall energy efficiency of this technology accounts for both the produced heat as well as the power. Both energy products are therefore represented in the corresponding power potential.

3.4. *Dimensionless technical biomass resource potential*

As is common, the technical potential is expressed in units of energy. The policy ambition of the case study region, however, is defined as the energy consumption that can be replaced by renewable energy sources. The objective for renewable energy hereby is twenty per cent, which is in line with the EU 20-20-20 targets. Because the unit in which the biomass resource potential assessment is expressed does not agree with the unit in which the policy ambition is stated, it is difficult to translate the results of the potential assessment to the policy domain. For that reason, this study introduces a dimensionless technical biomass potential to match the units of the potential assessment with the policy ambition. This dimensionless potential is calculated by dividing each technical biomass potential by the total energy consumption in the case study region – which for Overijssel is 87 PJ. The data on energy consumption is obtained from (Rijkswaterstaat, 2013). The dimensionless technical potential hence describes the percentage of energy consumption that can potentially be replaced by bioenergy. It is argued that this simple transformation will facilitate policy analysis.

4. Results

The proposed methodological framework has been applied to the case study region of Overijssel to assess its biomass resource potential. The technical biomass potential is found by evaluating the availability of biomass resources and by taking various technological conversion routes into account. A technical potential is hereby computed for each energy product – heat, power and fuel – within two bounding scenarios – *current case* and *innovation*. The resulting six potential values represent the amount of bioenergy that can be produced based on the remaining resources and the envisioned technological developments in the region. These technical potential values are subsequently made dimensionless to allow comparison with the policy ambition of the province of Overijssel. The results of this assessment are given below.

4.1. *Composition of the biomass potentials*

Data on biomass supply is collected to compute the different biomass potential values. These potentials are given in Table 4 and Fig. 3. The results indicate that a considerable amount of biomass is theoretically available in the province of Overijssel: 30.78 PJ. The composition of this potential shows that the categories agricultural residues, manure and municipal solid waste each have a major share in the theoretical potential. More specifically, residues from fodder crops, hay from grassland and pig manure contribute most. These types of biomass correspond to the main agricultural activities in the province, which is dominated by pasture land, the cultivation of fodder and animal husbandry. Reed is another biomass type with a considerable contribution to the theoretical potential. It is found that natural areas in the province are widely covered with reed. A major share of the potential is also taken by domestic waste. Although the province is characterized as rural, the urban agglomerations raise the population density and thereby the amount of domestic waste.

Calculation of the technical potential brings a significant reduction in the theoretical potential. It is found that approximately a third of the theoretical potential (11.17 PJ) is available for bioenergy. Applying the technological limitations reduces the theoretical potential even further: the average technical potential is 2.72 PJ. This indicates that less than a tenth of the theoretical potential can be converted into bioenergy. The losses in biomass potential mainly occur in the availability assessment, because some relevant biomass streams become unavailable for bioenergy. Agricultural residues and hay from grassland are unavailable due to competitive demands, while municipal solid waste is already being used for the production of energy. The availability assessment has therefore changed the composition of the theoretical potential. Potential is now shifted towards manure and biomass from the maintenance of nature reserves, such as reed and landscape wood. The composition changes again after the technological scenarios are applied. It is seen that the role of manure diminishes in the technical potential, because the energy conversion technologies for manure are not efficient enough to translate the available biomass into the technical potential. This dynamic might even discourage the use of manure for bioenergy, if other end products from manure become more attractive, such as mineral extraction. Reed and landscape wood are therefore the main contributors to the technical biomass potential.

Table 4
Biomass resource potentials: amount of biomass resource; theoretical potential; theoretical potential after availability assessment; and the average technical potential.

Main category	**Type of biomass**	**Amount of dry biomass** (kt)	**Theoretical potential** (PJ)	**Available theoretical potential** (PJ)	**Average technical potential** (PJ)
Woody biomass	Landscape wood	55.5	1.02	1.02	0.79
	Waste wood	15.7	0.32	0	0
Agricultural residues	Grains	26.3	0.48	0.05	0.02
	Commercial crops	0.7	0.01	0	0.00
	Fodder crops	414.7	7.67	0.77	0.36
	Sugar beet	3.4	0.06	0.01	0.00
Grasses	Hay from grasslands	333.8	6.18	0.19	0.09
	Reed	145.0	2.49	2.49	1.18
	Natural grasses	5.1	0.09	0.09	0.04
Manure	Cattle manure	48.2	0.70	0.70	0.03
	Veal manure	23.3	0.34	0.34	0.01
	Chicken manure	96.1	1.40	1.40	0.05
	Pig manure	297.6	4.11	4.11	0.15
Municipal solid waste	Domestic waste	185.9	2.73	0	0
	Coarse domestic waste	24.9	0.37	0	0
	Organic waste	106.5	1.60	0	0
	Paper waste	70.5	1.21	0	0
Total		**1853.2**	**30.78**	**11.17**	**2.72**

4.2. *Dimensionless technical biomass potential*

As the province of Overijssel is committed to the EU 20-20-20 strategy, it has set the target to raise the share of renewable energy sources in the total energy consumption to 20% by 2020. A pivotal position is assigned to bioenergy. A share of at least 14% is specified as the goal for bioenergy. Reasonable achievements have been made in recent years to achieve this policy ambition. The share of bioenergy in total energy consumption had grown to 5.2%

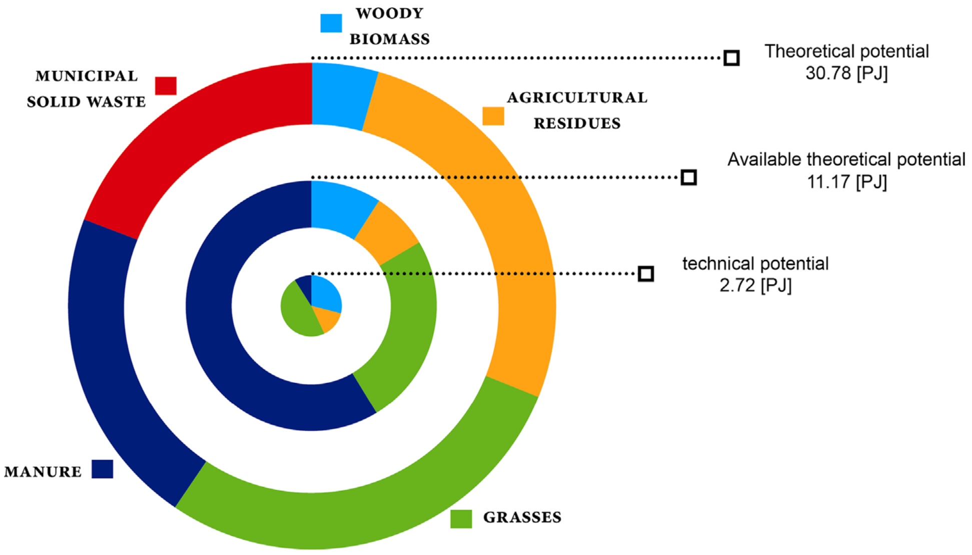


Fig. 3. Calculated biomass resource potentials.

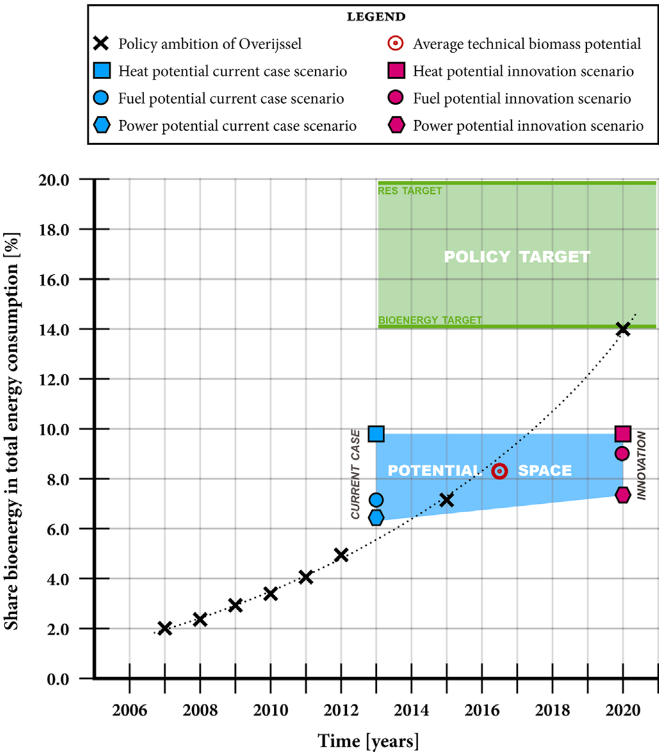


Fig. 4. Dimensionless technical potential vs. time for both bounding scenarios and each energy product. The area spanned by these six potential values is the potential space. The policy target of the province of Overijssel is also drawn as the green zone. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

Table 5
Dimensionless technical biomass potential for each scenario and policy ambitions of the case study region.

Energy product	Dimensionless technical potential (%)	
	Current Case	Innovation
Heat	4.5	4.5
Power	1.3	2.2
Fuel	2.0	4.1
Scenario average	2.6	3.6
Total average	3.1	
Description of dimensionless potential and policy ambitions	Dimensionless potential value (%)	
Theoretical potential	35.3	
Available theoretical potential	12.8	
Average technical Potential[b]	3.1	
Policy ambition	14–20	
Established ambition in 2012	5.2	
Total potential in region[a]	8.3	

[a] The sum of the established ambition and the average technical potential.
[b] The average technical potential of the current case and innovation scenario.

in 2012. There is still a large gap between the current share and the desired policy target, however. To facilitate the transition to bioenergy, an intermediate goal of 7.2% has therefore been specified for 2015. The policy ambition of the province is shown in Fig. 4, in which the share of bioenergy in the total energy consumption is plotted against time. Past achievements and current objectives are marked with a cross. The policy target of 14% bioenergy is highlighted in green.

The dimensionless technical potential, as defined, permits a comparison between the six dimensionless technical potential values and the province's policy ambition. These six technical potential values are also plotted in Fig. 4. Numerical values are given in Table 5. It should be noted that the current share of bioenergy (5.2%) is added to all dimensionless potential values in Fig. 4, since the computed potential values only describe the remaining potential. The three potential values – heat, power and fuel – for the *current case scenario* are here assigned to 2013, while the potentials for the *innovation* scenario are assigned to 2020. A blue area is subsequently drawn between these six potential values. This area, called the potential space, places the technical biomass resource potential in a temporal dimension bounded by the two scenarios. This potential space describes the share of bioenergy in the total energy consumption that can potentially be achieved, based on the biomass resources in Overijssel.

The average dimensionless technical potential is hence located at the center of the potential space and has the value of 8.3%. The average bioenergy target that the province can potentially reach is thus a share of 8.3% in the total energy consumption. There is therefore a clear gap between the province's policy target and the assessed bioenergy potential. The policy target of 14% bioenergy share is therefore unlikely to be met with the current biomass supply in Overijssel.

4.3. Policy measures

Some flexibility in biomass potential is nevertheless observed. The technical potential value for heat (9.7% for both scenarios) constitutes the upper edge of the potential space. A policy focus on heat production – e.g. coupling biomass resources with heat demand – will therefore increase the biomass potential of the province. On the other hand, the lower edge of the potential space is shaped by the technical potential for power. It follows that most efficiency losses occur in the production of electricity from biomass. Solely producing power with the available biomass is thus not beneficial for achieving the Overijssel policy target. One can see in Fig. 4, however, that technological innovations will increase the technical potential for power as time passes. A similar increase is seen for the technical potential for fuel. These improvements are related to future innovations in the province of Overijssel. Since the *innovation* scenario assumes a key role for pyrolysis in the years to come, it is envisioned that the conversion of biomass to biofuel and the utilization of these fuels in efficient power solutions will happen more frequently. Innovation policy that promotes the application of novel, energy-efficient conversion technologies – e.g. by technology forcing or strategic niche management (Geels, 2002) – would therefore be beneficial.

Although technological innovations offer improvements in the technical biomass potential, it is still evident that the biomass resource potential of the province – as described by the potential space – does not match the desired policy target. The policy ambitions of the province are thus affected: additional policy measures are therefore required to cope with the inadequate supply of biomass resources, so that the policy target can either be fully met or approximated as closely as possible.

Consideration may be given, first, to an import policy for biomass resources, to bridge the gap between the potential space and the policy target. Biomass import is a straightforward solution to raise the physical supply of biomass resources in the province. A considerable quantity of biomass would need to be imported, however, to meet the bioenergy target: the provincial supply would need to be almost doubled. On the other hand, no physical biomass is needed if bioenergy is directly imported as green electricity: only the demand for electrical bioenergy would need to be encouraged in the province. Importing green electricity is therefore considered a simple yet effective measure in the short term.

Even though biomass import does enable the policy target to be met, it remains undesirable for the renewable energy ambitions of the province, since the policy emphasizes the utilization of local resources within Overijssel. Tapping into external biomass resources does not fit the preference for provincial self-sufficiency. Biomass import would even increase import dependency. Unprocessed biomass has a low energy density – i.e. large volumes with low energy content – so the transport of biomass to Overijssel might also seem inefficient. Furthermore, since imported biomass requires additional energy conversion capacity to be built, it is less advantageous than directly importing bioenergy as green electricity or even green gas. Biomass import will hence incur political and physical resistance. Biomass, or bioenergy, import is nevertheless inevitable. Following the envisioned bioenergy transition path – as shown in Fig. 4 – a serious import policy will be inevitable at least in the three years preceding the target year of 2020. As a consequence, policy makers are challenged to shape the political boundary conditions for bioenergy import. For example: is green electricity import an acceptable alternative to compensate for an inadequate technical biomass potential? And is bioenergy accounted for according to its production location or the resource's origin? Furthermore, by taking the policy ambition of the European Union for biofuels as an example, it is noted that the import of biofuels will play a relevant role in the achievement of national policy targets (Pacini, Silveira & Da Silva Filho, 2013). As international trade of biofuels is growing (Heinimö & Junginger, 2009), it is expected that biofuel trade will also manifest itself on the local level as a solution to meet local policy ambitions.

Second, the inadequate supply of biomass can be increased by implementing a policy to encourage the allocation of biomass resources to energy production. As this study has shown, significant losses in biomass potential occur due to the unavailability of agricultural biomass for bioenergy. Agricultural biomass here refers to hay from grassland and all agricultural residues. Since the local market for agricultural biomass is competitive and price driven, the allocation of agricultural biomass can be encouraged with financial incentives that favor bioenergy. Any interference in the market, however, should be done carefully, to avoid undesired dislocation effects to occur. More specifically: as agricultural biomass is allocated to the bioenergy sector thanks to the encouraging measures, there will still be a demand for agricultural biomass in the agricultural sector. It is thus expected that the agricultural sector will satisfy its own demand with imports. Since agricultural biomass could also initially be imported for the purpose of bioenergy, it is unnecessary to disrupt the regional market for agricultural products. It is therefore argued that the provincial government has the task to encourage the utilization of agricultural products for bioenergy, without significantly affecting the current operations of the agricultural sector.

Third, by reducing the total energy consumption in the province, the inadequate supply of biomass could still be sufficient to meet the policy target. Since the province's policy target is specified as the share of bioenergy within total energy consumption, it follows that a decrease in energy consumption will increase the share of bioenergy for a constant amount of biomass. It would therefore be beneficial for the province to pursue policies to save energy. It is found that the bioenergy target of 14% can be met with the current supply of biomass, if Overijssel were to consume approximately 40% less energy. Since this reduction of energy consumption is a challenging target as such, it is not realistic to think that the bioenergy targets could be met by solely implementing energy saving policies. A significant improvement of the dimensionless technical biomass potential is nevertheless possible. Policies for energy efficiency should hence be considered as additional support for the province's bioenergy ambitions.

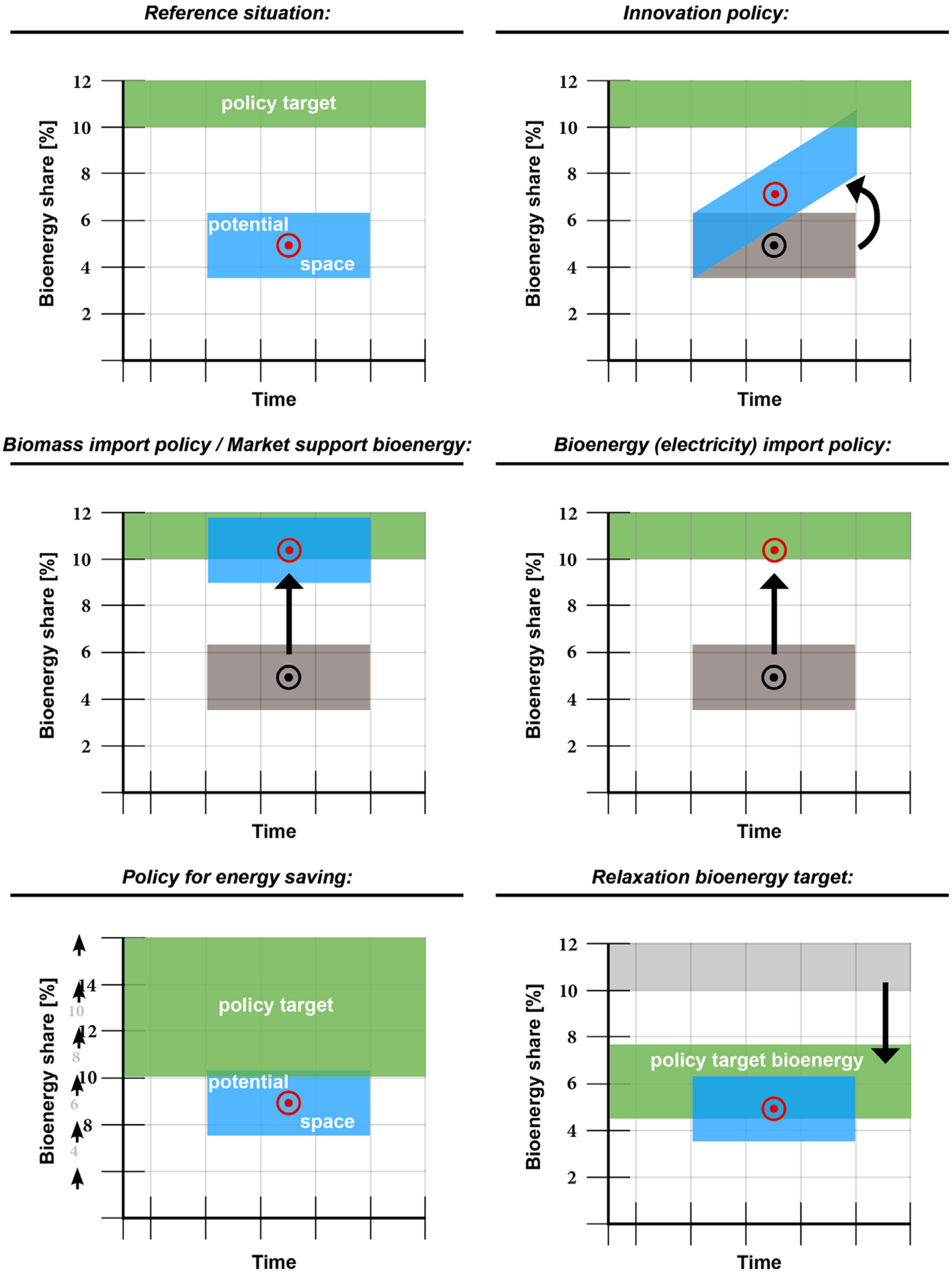
As an alternative measure to cope with the mismatch between the biomass resource potential and the province's bioenergy ambition, it is reasonable to propose a relaxation of the bioenergy target without compromising the overall renewable energy target. The province is politically committed to the EU target of 20% renewable energy in total consumption. This has placed a great emphasis in public on bioenergy, but the envisioned bioenergy target of 14% is not politically binding on the province. It is therefore conceivable that this bioenergy objective might be relaxed by acknowledging that the target is too ambitious. Since a lower bioenergy target is easier to meet, the province's bioenergy ambition can be achieved with the current biomass resource potential. However, this measure requires other renewable energy sources to compensate for the reduced share of bioenergy. A policy focus on diversification of the renewable energy sources is thus recommended to allow a more realistic bioenergy ambition based on the present biomass resource potential.

All in all, multiple policy measures can be conceived to close the gap between the biomass resource potential of the province and the desired bioenergy target. While technological innovations maximize the conversion potential of biomass to bioenergy, import policies and market support for bioenergy raise the physical amount of biomass resources. Policies for energy saving will furthermore increase the actual share of bioenergy. The biomass resources can moreover be matched with the policy ambition by relaxing the bioenergy target and diversifying to other renewable energy sources. Although these five policy measures are not mutually exclusive, their effect on the biomass resource potential – as described by the potential space – is given in Fig. 5. This figure shows that bioenergy policy analysis is facilitated by introducing a dimensionless technical potential to the common framework of a biomass resource potential assessment.

4.4. Policy outlook

The current bioenergy policy of the province is merely focussed on the commitment of 20% renewable energy in 2020. Policies beyond this target are not present. The corresponding road-map for bioenergy is therefore limited to the target year of 2020. This road-map is updated frequently – usually once in a few years with a new policy program – to cope with local dynamics in the bioenergy sector and to include new research findings. However, the outcome of this study is not fully reflected in the latest provincial policy program for bioenergy (Province of Overijssel, 2013). As this study proposes multiple policy measures to raise the biomass resource potential, the province is encouraged to formulate a matching bioenergy policy that could serve the short-term targets, but that could also set the basis for long-term bioenergy development.

Although a provincial bioenergy policy beyond 2020 is missing, some trends are currently observable that could shape this long-term bioenergy policy. First, the notion of a biobased economy is emerging in the province, as it is believed that more value can be added to local biomass if that biomass is not allocated solely to the purpose of energy. A regional biobased economy will thus change the utilization of local biomass. This development is predominantly driven by the still large manure surplus in the province in combination with problems to increase manure digestion. Mineral


Reference situation:

Innovation policy:

Biomass import policy / Market support bioenergy:

Bioenergy (electricity) import policy:

Policy for energy saving:

Relaxation bioenergy target:

Fig. 5. Proposed five policy measures and their effect on the potential space of the biomass resource potential assessment.

extraction from manure is therefore considered as a future alternative to manure digestion. As a result, multiple research activities to convert manure into minerals are currently observed in the province. Successes in the current innovation policy will therefore shape the long-term bioenergy outlook of the province.

Second, as the development of bioenergy touches upon multiple policy fields other than energy, it is noted that future attention will be given to the integration of bioenergy policy with other related policy fields (Province of Overijssel, 2013). The proposed policy measure to allocate more agricultural biomass to energy production can initiate such integration between provincial bioenergy policy and agricultural policy.

Third, while the province keeps stressing its initial preference for self-sufficiency, it has recently recognized that biomass import will be necessary for large scale bioenergy production (Province of Overijssel, 2013). This development indicates that an elaborate import policy for bioenergy will most likely be formulated for the period beyond 2020. Since this study argues that biomass import is inevitable to meet the current targets, it is possible that the current policy program might be updated with more provisions on biomass import. As a result of import policy, it is expected that local biomass resources will have to compete with imported biomass for utilization. This development will shape the long-term bioenergy outlook of the province.

5. Conclusion

As energy from biomass occupies a pivotal position in the renewable energy strategy of numerous regions, it is often necessary for policy makers to assess the regional resource potential for energy from biomass. Taking the Dutch province of Overijssel as the case study region, this paper has presented a biomass resource potential assessment to determine a theoretical and technical biomass potential. Resource-focused statistical analysis is used as the overarching methodology to compute the theoretical potential, which is subsequently cascaded into the technical potential by taking technical limitations and competing allocation of biomass into account. The technical potential is hereby calculated within two scenarios and for three different energy products: heat, power and fuel.

The biomass resource potential assessment indicates that 30.78 PJ of bioenergy is theoretically available in the province of Overijssel. Although this is a considerable theoretical biomass supply, it reduces to only 2.72 PJ for the technical biomass potential. This loss is mainly due to the unavailability of agricultural biomass, the established use of waste for energy, and the inefficient conversion of manure to bioenergy. Biomass from the maintenance of nature reserves, such as landscape wood and reed, remains the main contributor to the technical biomass potential. Proper logistics and efficient nature maintenance are thus required to fully exploit, or even increase, the potential of biomass from nature. On the other hand, either efficiency improvement in digesters or innovation in manure conversion technologies are needed to benefit from the large surplus of manure.

Since the policy ambition of the province of Overijssel is defined as the amount of energy consumption that can be replaced by renewable energy sources, it is beneficial for further policy analysis to translate the outcome of the biomass resource potential into the policy domain. As a second objective, this study has introduced a dimensionless technical potential by dividing each technical potential with the total energy consumption in Overijssel. The dimensionless technical potential hence describes the potential share of bioenergy in the current energy consumption, which will greatly assist the analysis of bioenergy policies in the province.

It has been shown that the average bioenergy target that the province can potentially reach is a share of 8.3%. The policy target, however, is set at a share of 14%. It is therefore clear that the assessed potential for bioenergy does not conform with the province's desired policy target. Although technological choices and innovations can be conceived to maximize the conversion of biomass to bioenergy, numerous other policy measures are still recommended to cope with the inadequate biomass potential. A policy of importing biomass and bioenergy can raise the biomass potential to the desired levels in the short term. This is therefore seen as an inevitable measure to meet the bioenergy targets. An import policy should therefore be included in the scope of policy makers. The physical supply of biomass can furthermore be raised by policies to encourage the allocation of agricultural biomass to bioenergy. Interference in agricultural markets should be done carefully, though, so that regular agricultural activities are not significantly disrupted. The actual share of bioenergy can also be increased by implementing energy saving policies. An alternative measure to meet the bioenergy targets is to relax the targets for bioenergy and compensate the reduced share of bioenergy with other renewable energy sources. Although this measure is politically undesirable, given the great emphasis publicly put on bioenergy, it is still a plausible option to consider.

All in all, the bioenergy ambition of the province of Overijssel is unlikely to be met with the current supply of biomass if no additional policy measures are taken. It can be concluded that the biomass resource potential assessment, as proposed here, is a valuable and robust tool to evaluate the potential of energy from biomass. Since the methodology of this assessment is also structured upon existing and accessible statistical data – largely gathered by the national statistics office – it can easily be applied to any other region. It has furthermore been demonstrated that the transformation to the dimensionless technical biomass potential facilitates policy analysis of bioenergy ambitions. This paper should therefore be considered as an effort to harmonize a quantitative assessment of the biomass resource potential with the process of bioenergy policy making. Policy research in line with this approach is thus welcomed.

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